Electrical Resistivity of SmAg, SmCu, and SmAu*

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The electrical resistivity of equiatomic phases of Sm with Cu, Ag and Au was measured down to 4.2°K. Anomalies were found at 10°K for SmCu and at 42°K for SmAg. The resistivity-temperature curve of SmAu has a maximum at 40°K and a minimum at 53.5°K.

1. INTRODUCTION

MANY equiatomic binary phases between the rare-earth elements and other metals have the CsCl-type crystal structure[1] and possess magnetic transitions at low temperature.[2–4] These transitions are clearly established by either magnetic susceptibility measurements or neutron diffraction. In many cases, an anomaly in the resistivity-temperature curve is also present at the transition temperature.[5] In alloys containing samarium with copper, silver and gold, it is rather surprising to find that under equilibrium conditions only SmAg has the CsCl structure, SmCu is orthorhombic of the FeB type and the structure of SmAu is complex and has not yet been determined. In this investigation, the electrical resistivity-temperature relationships for these phases were measured and some of the anomalies found in these curves can be correlated with previous measurements of susceptibility.

2. EXPERIMENTAL

The alloys of equiatomic composition were prepared by induction melting of the constituents in tantalum tubes, sealed by spot welding, under an argon atmosphere. Samarium, obtained from American Potash Corporation was 99.9% pure and Cu, Ag and Au were of purity greater than 99.99%. An exothermic reaction was observed in all cases, but was particularly strong for SmAu. The melting points of the compounds were estimated to be approximately 1570°K for SmAu and 1300°K for SmCu and SmAg. The ingots were then remelted in tantalum tubes having an inside diameter of 0.28 cm and about 8 cm long. The remelting was repeated two or three times in order to minimize casting defects. The thin-wall tantalum tube (0.03 cm) surrounding the cast specimen was then removed by machining the assembly to a final diameter of about 0.2 cm. The SmCu and SmAg alloys were annealed in vacuum for one week at 550°C and the SmAu phase was annealed for 9 h at 850°C.

The resistivity measurements were made by the four-probe method with current reversal. The temperature varying from 4.2°K to room temperature was measured by copper–constantan thermocouples pressed against the specimen. The uncertainties in the reported

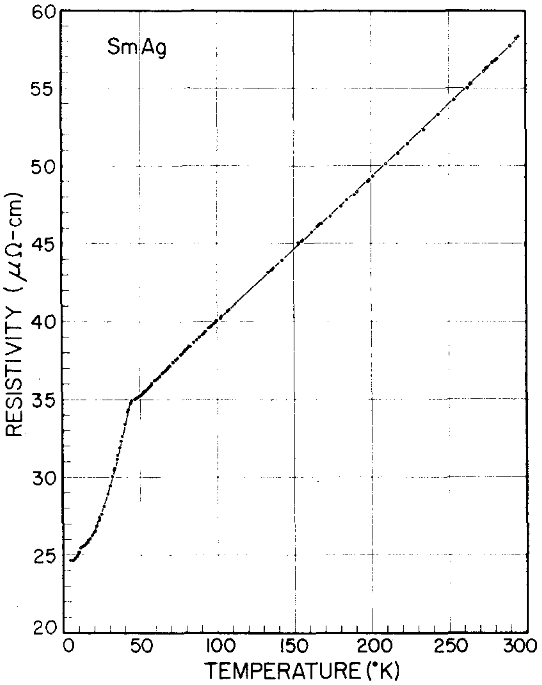

FIG. 1. Resistivity-vs-temperature curve of SmAg phase.

values of resistivity are estimated to be about ±2.5%, and the uncertainty in the temperature measurement is about ±0.3°K. For each alloy composition at least two specimens were measured and the results were reproducible.

3. RESULTS

3.1. SmAg Phase

Among the three phases studied in this investigation, SmAg is the only one having a CsCl-type crystal structure. The resistivity–temperature curve for SmAg is shown in Fig. 1. This curve is very similar to those previously reported for several similar CsCl-type phases involving rare-earth elements.[5] A very-well-defined transition exists at 42°K and above this temperature, the resistivity varies linearly with temperature. This linear

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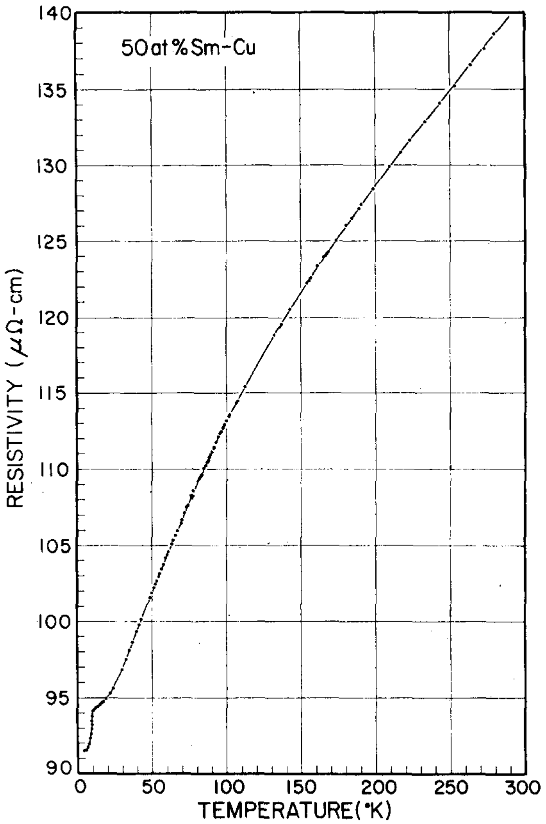

FIG. 2. Resistivity-vs-temperature curve of SmCu phase.

relationship may be expressed by

$$\rho(T) = (S + 0.093T)\mu\Omega\cdot\text{cm},$$

in which S is a constant equal to 30.7 $\mu\Omega\cdot$cm. The difference between S and the resistivity at 4.2°K is the fraction of the resistivity contributed by the spin

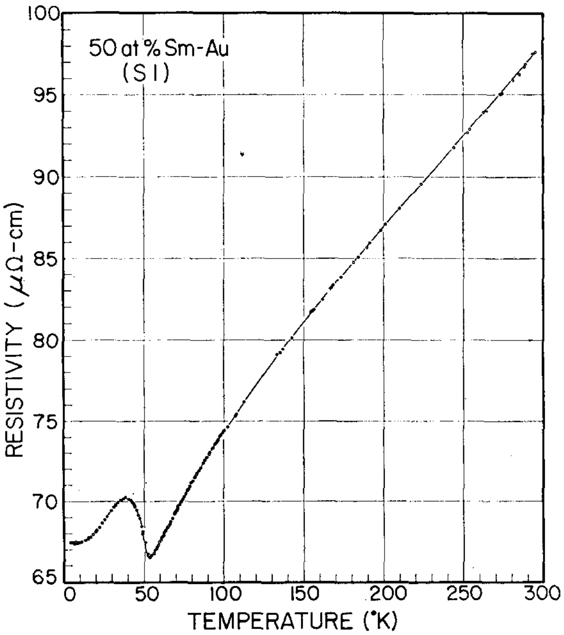

FIG. 3. Resistivity-vs-temperature curve of SmAu phase.

disordering scattering of the conduction electrons. For a number of rare-earth alloys having the CsCl structure the electrical resistivity anomaly similar to that shown in Fig. 1 was related to a magnetic transition measured by either susceptibility or neutron diffraction. In the present case of SmAg, Walline and Wallace detected such a transition[4] but did not report quantitative results because the susceptibility change was very small. No neutron diffraction experiments have been reported so far for SmAg. The anomaly observed here in the electrical resistivity is well defined and its shape suggests that it is due to a ferromagnetic to paramagnetic transition.

Below 42°K, the resistivity of SmAg could be fitted to a parabolic curve depending on T^2 down to about 11°K at which temperature a second still unexplained anomaly occurs. The resistivity levels off between 7°

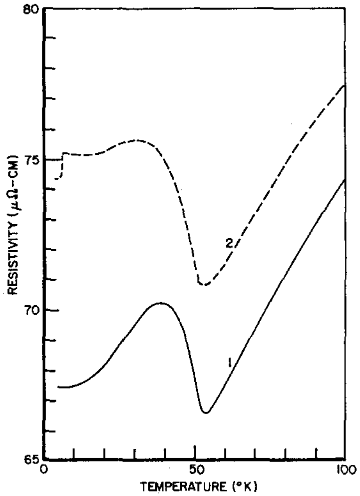

FIG. 4. Comparison of the resistivity-vs-temperature curves of the annealed (1) and as-cast (2) samples of SmAu phase.

and 4.2°K, with an apparent residual resistivity of 24.6 $\mu\Omega\cdot$cm, which is very high in comparison with many other CsCl-type rare-earth phases.

3.2. SmCu Phase

The SmCu phase is orthorhombic of the FeB type and a magnetic transition has been reported by Walline and Wallace at 40°K.[3] As shown in Fig. 2 the resistivity curve above about 20°K is concave upward up to about 40°K, and concave downward above this temperature and the inflection point around 40°K is probably related to the magnetic transition. However, another very sharp anomaly in the resistivity curve occurs at 10°K. Below this temperature, the curve can be fitted by a T^5 relationship and levels off at 5°K, with a rather high residual resistivity value of 91.5 $\mu\Omega\cdot$cm. Additional susceptibility or neutron diffraction experiments will be required to elucidate the nature of the strong anomaly in the resistivity curve at 10°K.

3.3. SmAu Phase

The shape of the resistivity–temperature curve for the SmAu phase shown in Fig. 3 is quite different from that of the Cu and Ag phases and presents a maximum at 40°K and a minimum at 53.5°K. Since no susceptibility or neutron diffraction measurements have been reported on this phase, it is difficult to correlate the anomalies in resistivity with magnetic transitions. In order to verify the reproducibility of the anomalies, electrical measurements were also performed on the SmAu phase in the as-cast condition, and the results are shown in Fig. 4. As expected, the resistivity of the as cast material is higher than that of the annealed one, but the minimum in the curve is located exactly at the same temperature of 53.5°K. The curves are slightly different at lower temperatures and the maximum is shifted down from 40°K to about 32°K. In addition, a sudden drop in resistivity is observed in the as cast alloy at 7°K. No reason can be offered for this abrupt discontinuity in the resistivity curve.

4. CONCLUSIONS

The electrical resistivity-vs-temperature curves of the three equiatomic phases of Sm with Cu, Ag and Au show several anomalies which are probably related to magnetic transitions. The fact that the curves show very little similitude is probably due in part to the different crystal structures of these three phases, which in turn indicates a lack of similarity in the alloying behavior of copper, silver and gold with samarium.

It should be pointed out that the SmCu and SmAu phases can be made to crystallize into a CsCl structure isomorphous with SmAg by rapid quenching from the liquid state.[6] However, in the process of quenching, these two alloys break up into small pieces only a few mm in length and no reliable electrical resistivity measurements have been obtained so far. Measurements on the rapidly quenched alloys would make possible a direct comparison of the magnetic properties of the three Sm phases with Cu, Ag, and Au with the same CsCl-type crystal structure.

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Magnetoelastic Resonances in Ferrite Memory Cores

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The acoustical resonant modes of a ferrite memory core have been identified and related to the flux configuration. A simple calculation is given which indicates the relationship of the amplitude of the resonance to the single-crystal parameters. The line width has been measured as a function of temperature and related to the relaxation of the permeability.

INTRODUCTION

Ferrite memory cores, in cyclic operation, generate a voltage which has been called magnetostrictive ringing. This effect has been a source of noise in memory. The problem of ringing in cores is analyzed in this report in terms of the magnetic parameters, anisotropy, and magnetostriction. Because of the high Q which is experimentally observed (100 to 3000) it will be assumed that the mechanical properties dominate the magnetic.

This report contains sections which describe (1) the experimental method of observing the resonance; (2) the modes of vibration of a core and how these are calculated; (3) the amplitude in terms of the magnetization, anisotropy, and magnetostriction; (4) the line width, or Q, in terms of atomic processes; and (5) the relationship between the observed resonances and the flux configuration of the core.

The subject of acoustic resonances in cores has been reported in the literature several times in the past. Butterworth[1] evolved an oscillator which is controlled by the mechanical Q of a toroid—the "magnetostrictor." Van der Burgt[2] (1953) carefully reanalyzed this device. In both cases, the toroids used were large in diameter. The mechanical resonance was taken to be described by the uniform radial expansion mode with the frequency given by

$$\omega = a^{-1}(E/\rho)^{1/2}, \tag{1}$$

where a is the mean radius of the device, E is Young's modulus and ρ is the density. This simple formula holds only for a toroid which has a large ratio of radius to wall thickness, i.e., the wall is infinitely thin. Buckens[3] (1950) published a calculation for two of the possible modes of toroid vibration which should be accurate for thick-walled toroids, and thus should describe the memory core. Buckens' formulas is applied, with modification, to the experiment on ferrite cores.

Van der Burgt's analysis was done in terms of the macroscopic parameters, such as permeability. In principle, these could be converted to the microscopic anisotropy and magnetostriction. However, since his

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